Kansas Agricultural Experiment Station Research Reports

Volume 0
Issue 10 *Swine Day (1968-2014)*

Article 343

1986

High nutrient-density diets for weanling pigs

Jim L. Nelssen

High nutrient-density diets for weanling pigs

Abstract

The increased occurrence of early weaning (4 weeks of age or less) of pigs has resulted in increased problems with a postweaning "lag" in many commercial swine units. The nursery is the weak link of most commercial swine operations. Attention to management factors that affect environment, health, and nutrition is the key to production success with early weaning. During the last decade, major research efforts have been expended by several universities to find nutritional programs to support satisfactory postweaning performance with early-weaned pigs. Ironically, many of the pigs used in these university trials were 4 weeks of age and weighed in excess of 15 lb at weaning. Weaning at 3 weeks of age results in many lightweight pigs (<10 >lb) that require increased nutrient density and diet palatability to maintain growth on a dry diet. If these pigs won't consume the diet, or fully utilize the nutrients in the diet, a "lag" in performance or even death can occur. Economic justification of feeding complex diets to 3-week-old weanling pigs must be considered by the individual swine producer. Prior to weaning, the sow provides the pig with about 16, equally spaced, highly digestible meals in a liquid form. This liquid diet contains approximately 30% protein, 35% fat, and 25% lactose on a dry matter basis. After weaning, pigs are normally fed a low fat, low lactose, high carbohydrate diet composed of cereal grain and soybean meal in a dry form. It is not surprising that a 10 lb pig does not immediately establish a social order I find the feeder, adjust to the drastic change in diet, and immediately start eating and gaining weight the first week after weaning. The objective of this paper is to provide justification for a high nutrient-density diet for early-weaned pigs and to give practical application of such a diet.; Swine Day, Manhattan, KS, November 20, 1986

Keywords

Swine day, 1986; Kansas Agricultural Experiment Station contribution; no. 87-133-S; Report of progress (Kansas State University. Agricultural Experiment Station and Cooperative Extension Service); 507; Swine; Weanling pigs; Diets

HIGH NUTRIENT-DENSITY DIETS FOR WEANLING PIGS

J.L. Nelssen

Introduction

The increased occurrence of early weaning (4 weeks of age or less) of pigs has resulted in increased problems with a postweaning "lag" in many commercial swine units. The nursery is the weak link of most commercial swine operations. Attention to management factors that affect environment, health, and nutrition is the key to production success with early weaning.

During the last decade, major research efforts have been expended by several universities to find nutritional programs to support satisfactory postweaning performance with early-weaned pigs. Ironically, many of the pigs used in these university trials were 4 weeks of age and weighed in excess of 15 lb at weaning. Weaning at 3 weeks of age results in many lightweight pigs (<10 lb) that require increased nutrient density and diet palatability to maintain growth on a dry diet. If these pigs won't consume the diet, or fully utilize the nutrients in the diet, a "lag" in performance or even death can occur. Economic justification of feeding complex diets to 3-week-old weanling pigs must be considered by the individual swine producer.

Prior to weaning, the sow provides the pig with about 16, equally spaced, highly digestible meals in a liquid form. This liquid diet contains approximately 30% protein, 35% fat, and 25% lactose on a dry matter basis. After weaning, pigs are normally fed a low fat, low lactose, high carbohydrate diet composed of cereal grain and soybean meal in a dry form. It is not surprising that a 10 lb pig does not immediately establish a social order, find the feeder, adjust to the drastic change in diet, and immediately start eating and gaining weight the first week after weaning. The objective of this paper is to provide justification for a high nutrient-density diet for early-weaned pigs and to give practical application of such a diet.

Baby Pig Digestion

Since the trend of weaning age is shifting to younger and younger pigs, it is necessary that feed manufacturers, swine producers, veterinarians, and educators have an understanding of the nutritional needs and biology of digestion of pigs from birth through 35 days of age. Webster's definition of weaning is "to accustom; to take food other than by suckling." Ironically, in swine production, little attempt is made to formulate diets for the pig with regard to changes from a liquid milk diet to a dry diet composed of mainly plant products. Yet, there is a profound difference between digesting sow's milk composed of casein, lactose, and fat, and mounting an enzyme attack on starch granules and plant proteins.

Economic considerations of pork production are forcing swine producers to be concerned with saving as many pigs as possible in an attempt to maximize profitability. The digestive capability of the gastrointestinal tract of the early-weaned pig plays a major role in nursery pig performance. Considerable research has been conducted to examine changes in pancreatic enzyme levels with age (Figure 1). Enzyme activity appears to be adequate within a few hours after birth and is especially prepared for digesting sow's milk. Recent research has indicated that the influence of age on the ability of the pig to digest dietary components is less important than the acclimation necessary to adjust enzyme levels to the dietary demands. Unfortunately, research data are not available on the amount of time necessary for enzyme acclimation by the early-weaned pig.

Enzyme System Development

Milk products are expensive relative to cereal grains. Thus, a conflict exists between diets that are suited to the digestive capacity of the young pig and diet cost. The real issue is to establish the rate at which the early-weaned pig can adapt to dietary ingredient changes. Early weaning diets (for pigs weaned at 14-21 days) often mimic the composition of sow's milk (Table 1). Over half of the gross energy available to the nursing pig is derived from fat. Yet, many researchers contend that the newly weaned pig does not utilize fat efficiently.

The digestive enzyme system of the young pig changes drastically during the first few weeks of life. Lactase, the enzyme that breaks down lactose, is high at birth and decreases with age. The enzymes amylase and maltase, necessary for the digestion of carbohydrate in cereal grains, are low at birth and increase with age. Since the nursing pig grows rapidly on sow's milk, it would seem that the enzyme systems capable of metabolizing lipids must be active at a very early stage of life. Pancreatic lipase, necessary for fat breakdown, begins to increase within a few days after birth and continues up to 6 weeks of age (Figure 2). Understanding the enzyme system of the newly weaned pig is a key in preventing the postweaning "check" often seen in commercial swine production.

Carbohydrate Metabolism

The carbohydrate sugars of interest in baby pig nutrition are lactose (milk sugar), dextrose (glucose), sucrose (sugar), and maltose (starch). Carbohydrate digestion begins with salivary digestion, continues in the stomach, and then in the small intestine where carbohydrates are prepared for absorption. Pancreatic enzymes, such as lactase and maltase, are located in brush border of the small intestine of the weaned pig. Cereal grains such as corn, milo, and wheat contain high levels of starch that are broken down to maltose and eventually glucose by the pig.

Of some concern for young pigs is the quantity of carbohydrate used in formulating high nutrient density diets. High levels of cereal grains in young pig diets could alter the osmolarity of the intestinal tract. With higher levels of glucose, as a result of carbohydrate metabolism in the intestinal tract, water will move across the mucosal wall of the intestine. Increased quantities of water in the intestinal tract could result in diarrhea in the newly weaned pig.

Fat Metabolism

Dietary fats consist mainly of triglycerides with some phospholipids, sterols and sterol esters. Triglycerides are hydrolyzed in the small intestine by the lipase in the pancreatic juice, and the monoglycerides and free fatty acids produced pass into micellar solution in the presence of the bile salts. Shorter chain fatty acids are transported through the body after uptake by portal blood. In contrast, longer chain fatty acids are synthesized within the intestinal wall to triglycerides and pass into the intestinal lymph.

A considerable amount of controversy exists as to the "ideal" source of fat for the newly weaned pig. Part of the discrepancy in fat sources by the young pig may be due to the level of fat in experimental diets and the methods of determining fat digestion. Since the fat content of sow's milk can be as high as 40% of the total dry matter, digestion of fat by the young pig should not be a limiting factor. Research has shown that the digestibility of fat in sow's milk is as high as 98%.

Effects of level of fat on the growth rate of early weaned pigs have been inconsistent. Researchers in the 1960's reported that increased fat in the diet did not improve feed efficiency and generally decreased rate of gain in pigs. In contrast, other workers have shown that coconut oil is rapidly digested by the weanling pig, and metabolism of lard, peanut oil, and corn oil is also quite high. European workers found that soybean oil and butterfat were superior sources of fat compared to beef tallow for the early weaned pig. Research at Kansas State University has shown fat digestibility to be quite high for the 21-day old pig (Table 2). This variable response to fat may be related to confounded effects caused by differences in the intake of other essential nutrients.

Protein Digestion

Relatively little digestion of proteins occurs in the stomach during the first 21 days of life in the pig, even though hydrochloric acid secretion begins to take place. The pancreas secretes enzymes for the initiation of protein digestion in the small intestine. When feed passes from the stomach into the small intestine, the pH is raised by the pancreatic juices and the bile, producing conditions for proteins and peptides to be acted on by the pancreatic enzymes. The two primary enzymes for protein digestion are chymotrypsin and trypsin.

A considerable amount of research has been conducted during the last few years in an attempt to understand the development of protein digestion in the young pig. North Carolina State researchers reported that weaning at 16 days of age tended to accelerate the development of the pig's ability to digest protein. In a similar study, these researchers found that soy protein increased the secretion of trypsin and chymotrypsin into the intestine. Likewise, researchers at University of Minnesota have shown that dietary ingredients have an influence on chymotrypsin and trypsin secretion in the young pig.

Several studies have clearly demonstrated that complex diets containing dried milk products (whey, dried skim milk, and casein) are superior to a simple grain-soybean meal diet for pigs weaned at 3 weeks of age (Table 3). Recent research from the University of Illinois showed that casein was more readily utilized by the 4-week-old pig than was soy protein. Thus, the time necessary for adaption of the young pig's enzyme system to plant proteins might limit utilization.

Practical Starter Programs for Early Weaned Pigs

As mentioned previously, early weaning often refers to weaning at 3 weeks of age or less. In modern nursery facilities, pigs are often weaned at 21 days of age onto an inferior diet, with pigs losing weight the first week postweaning. In fact, weaning at 3 weeks of age in commercial operations commonly results in nursery pigs ranging in age from 14 to 28 days. Obviously, early weaning results in several lightweight pigs (<10 lb) that require increased nutrient density and diet palatability to maintain growth on a dry diet. To provide optimum nutritional management for the early weaned pig, research has recently been conducted at Kansas State University evaluating a three-phase starter program during the nursery phase of swine production. Listed below is a description of this starter program, with a suggested feeding interval for each phase.

Three-Phase Starter Program

Item	Description	Recommendation
Phase One:	High Nutrient-Density Diet	Fed to pigs until body weight is at least 15 lb
Phase Two:	1.25% lysine, whey, corn-soybean diet	Fed to pigs from 15 to 25 lb
Phase Three:	1.10% lysine, grain-soybean diet	Fed to pigs until body weight is approximately 50 lb

The following discussion explains each phase.

I. Phase One: High Nutrient-Density Diet.

Starter diets for pigs weaned at 14 to 21 days of age have been the topic of considerable speculation because of the variation in results. Swine producers have grown accustomed to seeing early-weaned pigs experience a postweaning "check", which often results in increased days to market in their production unit. In fact, many producers have replaced 21-day weaning with a 28-day weaning program, simply because of the adverse performance of pigs during the initial week in the nursery. A high nutrient-density diet (HNDD) is a type of milk-based diet that is intended to improve the initial starter pig performance. Various formulations of HNDD have been tried in commercial swine production units with variable success.

There are actually two types of HNDD that have been formulated for early-weaned pigs. The first approach has been to formulate diets to be as similar to sow's milk as possible, but in a dry form. Diets based on total milk protein with added vitamins and minerals are very successful, yet prohibitively expensive. In a similar category, is a HNDD formulated with an understanding of the digestive capacity of the young pig, but with some awareness for economic constraints. Such a HNDD diet is described in Table 4.

Three trials have been conducted at Kansas State University to evaluate the effects of a HNDD diet on starter pig performance. Trial 1 was an on-farm trial and involved 208 crossbred pigs weaned at approximately 21 days. The pigs were divided into light (10.7 lb) and heavy (14.3 lb) groups. Half of the light pigs were fed HNDD for 2 weeks followed by a 20% whey, corn-soybean meal diet for 1 week, and half of the heavy pigs were fed HNDD for 1 week and a 20% whey diet for 2 weeks. The rest of the pigs were fed a 20% whey, corn-soybean meal (C-SBM) diet for 3 weeks. After 3 weeks, all pigs were fed a 1.15% lysine corn-soybean meal diet. Pig weights were recorded on days 7, 14, and 42 postweaning, and all feed additions recorded.

Trial 2 was conducted at the KSU Swine Research Unit and involved 70 weanling pigs (21 days of age). Average initial pen weights ranged from 6.5 to 9.6 lb. Pigs averaging 9.3 lb or more were fed either HNDD for 1 week and a 20% whey diet for the next 4 weeks or a 20% whey diet for 15 weeks. Pigs weighing less than 9.3 lb were fed either HNDD for 2 weeks and a 20% whey diet for 3 weeks, or a 20% whey diet for 5 weeks. Pig weights and feed consumption were obtained weekly for 5 weeks.

Trial 3, also conducted at the KSU Swine Research Unit, utilized 80 weanling pigs (21 days old). Experimental treatments were as follows:

1. 1.25% lysine, C-SBM diet for 5 weeks.

2. 20% dried whey diets for 2 weeks, followed by a 1.25% lysine, C-SBM diet for 3 weeks.

3. HNDD for 1 week, followed by a 1.25% lysine C-SBM diet for 4 weeks.

4. HNDD for 1 week, a 20% whey diet for the next week followed by a 1.25% lysine, C-SBM diet for 3 weeks.

Initial average weight per pen ranged from 10.3 to 22 lb. Weekly pig weights and feed consumption were recorded.

The results of Trials 1, 2, and 3 are shown in Tables 5-7. In Trial 1, both the light and heavy pigs fed the HNDD regime gained faster (6%) and more efficiently (14.5%) than pigs fed the 20% whey diet (Table 5). All weight classes of pigs fed HNDD in Trial 2 gained more weight and were slightly more efficient than the pigs fed the 20% whey diet at both 1 and 5 weeks postweaning (Table 6).

Combining all the groups in Trial 2, it can be shown that HNDD markedly increased average daily gain through day 35 (Figure 3). In Trial 3, maximum performance for pigs weighing 12.5 lb or less was attained at 2 and 5 weeks when pigs were fed a HNDD for 1 week and a 20% whey diet for the next week (Table 7). For pigs weighing 14.1 lb or more in Trial 3, those fed the 20% whey C-SBM diet for 2 weeks outperformed those fed the other treatments after 2 or 5 weeks in the nursery.

From these studies, it can be seen that there is an advantage in feeding HNDD to smaller and/or younger pigs in the initial part of the starter period. The reason for the improved performance is most likely the fact that the young pig is better able to digest the milk products in the HNDD than the grain in a grain-SBM diet. Since the young pig is better able to utilize lactose from milk products than starch from cereal grains, the pig's daily metabolizable energy (ME) intake is increased. Also, since milk protein is digested better than cereal protein, and HNDD contains a larger complement of amino acids, the pig's daily intake of amino acids is also increased. Because of these factors, the young pig can use the increased amount of available nutrients in HNDD for early growth and, thus, postweaning lag can be decreased.

II. Phase Two: Whey Starter Diet

The transition from a HNDD diet to a more economical, starter diet is a key in a successful starter program. Studies conducted at Kentucky, Ohio State, Purdue, and Cornell Universities have shown the benefits of adding dried whey (minimum of 10%) to starter pig diets. In a study conducted at Kansas State, dried whey was added at 0, 10, 20 or 30% to a milo-soybean meal diet. A level of 1.2% lysine was maintained and 4% corn oil was added to each diet. Pigs fed diets containing 20% whey gained faster than pigs fed diets containing 0 or 10% added whey (Table 8). Therefore, current recommendations for the second phase starter diet are 15-20% added dry whey.

The lack of response to dried whey in some studies may be related to the type of whey utilized. A recent study (Table 9) demonstrated no response to a feed grade whey, whereas an edible grade dried whey improved daily gain and feed intake. This difference in whey source may be related to excessive drying temperature or salt or ash content.

Several experiments have been conducted to determine the lysine requirement for pigs weaned at 3 to 5 weeks of age. The NRC (1979) lists the lysine requirement of 11.0 to 22 lb pigs at .95% of the diet. Researchers at the University of Nebraska have conducted an experiment using a 2 x 6 factorial design (two levels of fat and 6 levels of lysine) to determine the lysine requirement of young pigs. The lysine levels ranged from .95% (basal) to 1.45% in .10% increments (Table 10). They concluded that pigs weighing 10.0 to 33.0 lb and fed practical diets containing 19% crude protein require 1.10 to 1.25 lysine. In agreement, a Kansas State study evaluated the lysine requirement of pigs fed a 20% dried whey-corn, soybean meal diet. This study (Table 11) suggested that 1.25% lysine was necessary to maximize daily gain and feed efficiency.

Researchers at Clemson University conducted two studies evaluating the caloric requirement of early-weaned pigs fed corn-soybean meal based diets containing 1400, 1500, 1600 or 1700 kcal of metabolizable energy (ME) per lb (Table 12). A significant quadratic effect of treament on gain was observed, with gains increasing until energy density reached 1600 kcal level. Average daily feed intake was lowest for pigs fed the 1400 kcal diet and the highest for those fed the 1300 kcal diet, but decreased as energy increased form 1500 to 1700 kcal. Feed-to-gain ratios improved linearly as caloric density increased, with the greatest improvement occurring between 1500 and 1600 kcal level. The researchers concluded that the caloric requirement for maximum gain and feed efficiency in young pigs is higher than that currently recommended by the NRC (1979), particularly for pigs weighing 22 to 44 lb.

The addition of an antibiotic or antibacterial to the diet has consistently resulted in a 10 to 25% improvement in daily gain. A recent trial conducted at Kansas State has shown that a beneficial interaction exists between copper sulfate and dired whey (Table 13). In almost all studies, the addition of copper sulfate has increased feed intake for the first 2 weeks after weaning. The effects of whey and copper sulfate appears to be additive in increasing feed intake and gain of pigs weaned at 3 to 4 weeks of age.

Trials conducted at Ohio State have demonstrated that the weanling pig's dietary selenium requirement is between .3 and .5 ppm. In 1982, FDA approved the addition of .3 ppm of selenium for weanling pig diets. Thulin et al. (1985) found that the addition of .3 ppm selenium to diets of weaned pigs resulted in 5% improvement in feed efficiency and a 7% improvement in daily gain (Table 14).

Too often, swine producers are so impressed with the phase two diet (Table 4) that they feed the diet until pigs weigh 40 to 50 lb. Unfortunately, this management practice increases the cost of producing pork, because the whey starter diet is more expensive than a simple grain-soybean meal diet.

III. Phase Three: Simple Starter Diet

The real objective of phase one and two of this starter program is to entice the young pig to start eating dry feed. Obviously, the ingredients used in formulating the previously described diets must match the developing digestive system of the young pig. Once nursery pigs have started consuming a considerable amount of feed, the goal should be to feed the most economical diet to ensure optimum performance (Table 15).

Once the early-weaned pigs reach a body weight of approximately 25 lb, feed intake is not as critical in diet formulation. In fact, highly palatable ingredients such as whey and fat can be removed from the nutritional program to lower diet cost (Table 4). Usually a grain-soybean meal diet fortified with vitamins and minerals will ensure the most economical performance.

An antibiotic or antibacterial is maintained in the phase three diet for the reasons previously mentioned. Copper sulfate (190-260 ppm) is added because of the known response of an increase in feed intake. The amino acid profile, especially lysine, is formulated at higher levels than recommended by the NRC (1979) in an attempt to optimize lean tissue deposition.

The phase three diet is fed through the nursery period or until pigs weigh approximately 50 lb.

Summary

A three-phase nursery program is recommended to provide optimum pig performance at a cost effective price. High nutrient-density diets have been introduced as highly palatable, easily digested diets for pigs weighing less than 15 lb. A short feeding duration provides nutrients for the early-weaned pig and prevents the postweaning "check" seen in many commercial production units.

Economic justification of feeding complex diets to 21-day-old weanling pigs must be investigated by the individual swine producer. There is clearly an advantage in performance for pigs fed HNDD. Advantages such as increased gains and decreased days to market weight and the managerial changes associated with them vary in economic value. A swine producer must realize that if properly utilized in the nursery phase, a HNDD will represent less than 1% of total feed necessary to produce a market hog. A high nutrient-density diet may serve as a valuable management tool for swine producers weaning pigs at 3 weeks of age or for an "all-in - all-out" swine production unit that needs improved facility usage.

Table 1. Composition and Energy Content in Each Component of Sow's Milk.

Component	% of Sow Milk	Kcal of Gross Energy per lb of Milk	% of Total Gross Energy
Lipid	7.5	550	56
Protein	6.0	270	28
Lactose	5.0	160	16

Adapted form V.R. Fowler in Recent Developments in Pig Nutrition.

Table 2. Digestion of Different Fat Sources in the 21-day Old Pig.[a]

Item	Crude Protein Digestibility (%)	Fat Digestibility (%)
Control	92.1	54.8
Corn oil	90.3	88.6
Choice white grease	89.4	87.1

[a]Fat sources replace cornstarch in the diets at an inclusion rate of 10%. Control diet included, 22% protein, 1.5% lysine, .9% calcium and .75% phosphorus.

Table 3. Dry Whey in Starter Diets for Weanling Pigs.

Dried Whey	Without	With
Daily gain, lb	.59	.64
Daily feed, lb	1.06	1.12
Feed/gain	1.84	1.79

Based on 28 experiments; 3,393 pigs (1976-83).

Table 4. Characteristics of a Three-Phase Starter Program.

Item	Phase 1: HNDD	Phase 2: Whey Start	Phase 3: to 50 lb Body Weight
Protein,%	20-25	18-20	18
Lysine, %	1.5-1.6	1.25	1.10
Added Fat, %	8-10	3-5	---
Dried Edible Whey, %	15-25	15-20	0-5
Dried Skim Milk, %	10-25	---	---
Fish Meal, %	0-3	3-5	---
Copper, ppm	190-260	190-260	190-260
Vitramin E, IU/ton	40,000	40,000	40,000
Selenium, ppm	.3	.3	.3
Antibacterial or Antibiotic	+	+	+
Physical Form	1/8" pellet	1/8" pellet	Meal Form

Table 5. Effect of High Nutrient-Density Diet vs. 20% Whey Starter Diet (Trial 1).[a]

Item	Light Pigs		Heavy Pigs	
	20% Whey	HNDD	20% Whey	HNDD
Avg. pig wt (lb)				
Initial	10.7	10.7	14.1	14.7
42 day	43.5	46.7	47.4	50.7
Avg. daily gain (lb)				
0 to 7 days	.23	.29	.19	.41
0 to 14 days	.40	.46	.43	.53
0 to 42 days	.78	.86	.79	.86
Feed/gain				
0 to 7 days	1.60	1.09	2.13	1.01
0 to 14 days	1.40	.99	1.45	1.17
0 to 42 days	1.55	1.26	1.65	1.48

[a]208 pigs (13 pigs/pen/treatment); trial length, 42 days.

Table 6. Effect of High Nutrient-Density Diet vs. 20% Whey for the Young Pig (Trial 2).

	Week 1				Week 5	
	ADG (lb)		F/G		Final Wt. (lb)	
Initial wt. (lb)	20% Whey	HNDD	20% Whey	HNDD	20% Whey	HNDD
9.6[a]	.33	.54	.96	.67	35.3	37.2
9.3[a]	.33	.38	1.22	.87	34.2	34.4
8.5[b]	.17	.35	1.28	.89	26.4	31.9
7.5[b]	.24	.40	1.49	.79	26.4	30.6
6.5[b]	.17	.38	1.17	.86	26.1	26.8

[a]HNDD fed for 1 week postweaning.
[b]HNDD fed for 2 weeks postweaning.

Table 7. Effect of Various Starter Diet Regimes on 14-Day Postweaning Performance (Trial 3).

	Pigs < 12.5 lb		Pigs > 14.1 lb	
Treatment	ADG (lb)	F/G	ADG (lb)	F/G
1[a]	.58	.97	.54	1.04
2[b]	.71	1.01	.93	1.26
3[c]	.71	1.06	.74	1.08
4[d]	.79	1.11	.77	1.09

[a]1.25% lysine C-SBM diet.
[b]1.25% lysine, 20% whey, C-SBM diet.
[c]HNDD for 1 week, 1.25% lysine C-SBM diet for 1 week.
[d]HNDD for 1 week, 20% whey diet for 1 week.

Table 8. Effect of Level of Dried Whey in Starter Pig Diet[ab].

	Level of whey, %			
	0	10	20	30
Avg. daily gain, lb	.69	.71	.77	.80
Avg. feed intake, lb	1.21	1.18	1.32	1.36
Feed/gain	1.74	1.74	1.70	1.70

[a]150 pigs (5 pigs/pen; 5 pens/treatment); 5-week study; Age, 15-23 days; avg. initial wt., 11.0 lb.
[b]Milo-SBM diet with 4% corn oil; 1.2% lysine.

Table 9. Dried Whey Source on Postweaning Swine Performance.

Item	Basal	Feed Grade	Edible Grade
No. Pigs	53	53	53
Weight, lb			
Initial	13.2	13.3	13.5
28-day	30.1[a]	29.9[a]	32.4[b]
Pig Performance, lb (day 0 to 28)			
Daily gain	.59	.58	.67
Daily feed intake	1.11	1.17	1.24
Feed/gain	1.88[a]	2.00[b]	1.87[a]

[abc]Means in the same row with different superscripts differ (P<.05).

Table 10. Performance of Weanling Pigs Fed Diets with Added Fat and Lysine[a].

Item	Added Fat, %	Lysine, % .95	1.05	1.15	1.25	1.35	1.45
Avg. daily gain, lb[bc]	0	.70	.77	.81	.87	.79	.79
	5	.70	.75	.82	.81	.77	.78
Avg. daily feed intake, lb[c]	0	1.34	1.42	1.49	1.56	1.21	1.42
	5	1.23	1.31	1.30	1.36	1.24	1.30
Feed/gain[bc]	0	1.90	1.85	1.84	1.79	1.53	1.80
	5	1.74	1.74	1.58	1.68	1.61	1.68

[a]Total 192 pigs (4 pigs/pen; 4 pens/treatment); 4-week trial; average initial weight, 12.1 lb.
[b]Linear lysine effect (P<.05).
[c]Quadratic lysine effect (P<.05).

Table 11. Effect of Level of Lysine in Starter Pig Diets Containing Dried Whey[a].

Item	Lysine, % .95	1.05	1.15	1.25	1.35	SE
Avg. daily gain, lb						
Week 0-2	.46	.46	.51	.55	.53	.04
Week 3-4	.97	1.03	1.01	1.08	1.03	.04
Week 5-6[bc]	.97	1.03	1.08	1.14	1.01	.02
Overall[bc]	.79	.86	.88	.92	.86	.02

[a]Avg. initial wt., 16.5 lb; Age, 21-33 days; 35 pigs/treatment; Basal diet corn-SBM, 20% whey at 17.4% protein.
[b]Linear effect (P<.05).
[c]Quadratic effect (P<.05).

Table 12. Calorie Requirements of Early-Weaned Pigs Fed Corn-Soybean Meal Diet.

Item	Energy Level kcal ME/kg Diet[a] 1400	1500	1600	1700
Trial 1[b]				
No. pigs	22	24	23	22
Avg. daily gain, lb[c]	.49	.59	.58	.53
Avg. daily feed intake, lb[cd]	.80	.91	.83	.72
Feed/gain[d]	1.68	1.68	1.46	1.36
Trial 2				
No. pigs	10	11	11	10
Avg. daily gain, lb[c]	.67	.74	.81	.72
Avg. daily feed intake, lb[cd]	1.16	1.28	1.17	1.01
Feed/gain	1.74	1.73	1.45	1.41

[a]Caloric density was adjusted using 4.27% solfa-floc or corn oil (1.12, 6.22, and 11.27% respectively); Calorie:protein ratio were maintained at approx. 16.5 kcal ME/g protein.
[b]Weaning age, 21 days; avg. initial weight, 12.5 lb; Trial 1 was 3 weeks and Trial 2 was 5 weeks.
[c]Quadratic effect (P<.05).
[d]Linear effect (P<.05).

Table 13. Effect of Copper Sulfate and Dried Whey Addition on Pig Performance.

Dried Whey (%):	0	0	5	10	15	20
Copper Sulfate (250 ppm):	-	+	+	+	+	+
Week 2						
Avg daily gain, lb[a]	.44	.46	.57	.55	.55	.59
Avg daily feed intake, lb[b]	.57	.59	.68	.70	.75	.73
Feed/gain[c]	1.38	1.31	1.20	1.31	1.38	1.24
Week 5						
Avg daily gain, lb[bcd]	.81	.86	.95	.92	.92	.95
Avg daily feed intake, lb[bc]	1.30	1.32	1.41	1.45	1.45	1.47
Feed/gain[ad]	1.61	1.53	1.50	1.57	1.59	1.54

[a]Linear whey effect (P<.05).
[b]Linear whey effect (P<.01).
[c]Cubic whey effect (P<.01).
[d]Copper sulfate effect (P<.05).
[e]Quadratic whey effect ((P<.05).

Table 14. Effect of Dietary Selenium on Pig Performance[a].

Item	Added Selenium 0	.3 ppm
ADG, lb[b]	.90	.97
Feed intake, lb	1.43	1.45
Feed: gain[b]	1.61	1.53

[a]Thulin et al., 1985. Average initial weight was 12.3 lb.; trial length 6 weeks.
[b]Selenium effect (P<.05).

Table 15. Schematic Description of the Management System for a Three-Phase Starter Program.

Nutritional Program	Starting Weight (lb)	Ending Weight (lb)
Phase 1: High Nutrient Density Diet	<12.0[a]	15.0
Phase 2: Whey Start Diet	15.0	25.0
Phase 3: Simple Start Diet	25.0	50.0

[a]Weaning weight of 21-day old pig.

FIGURE 1
DIGESTIVE ENZYME ACTIVITY
IN YOUNG PIGS

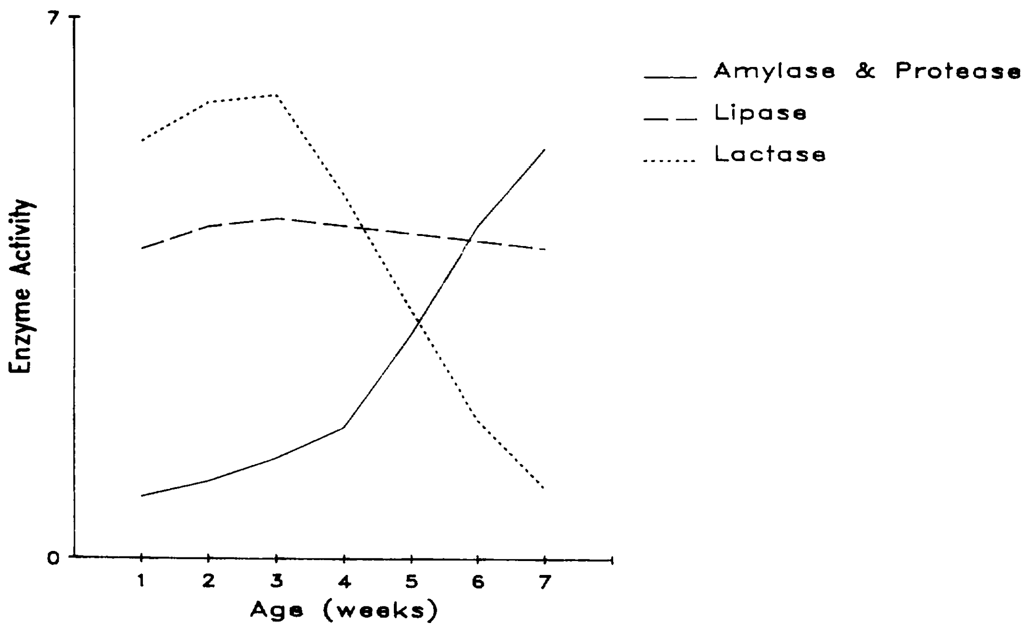
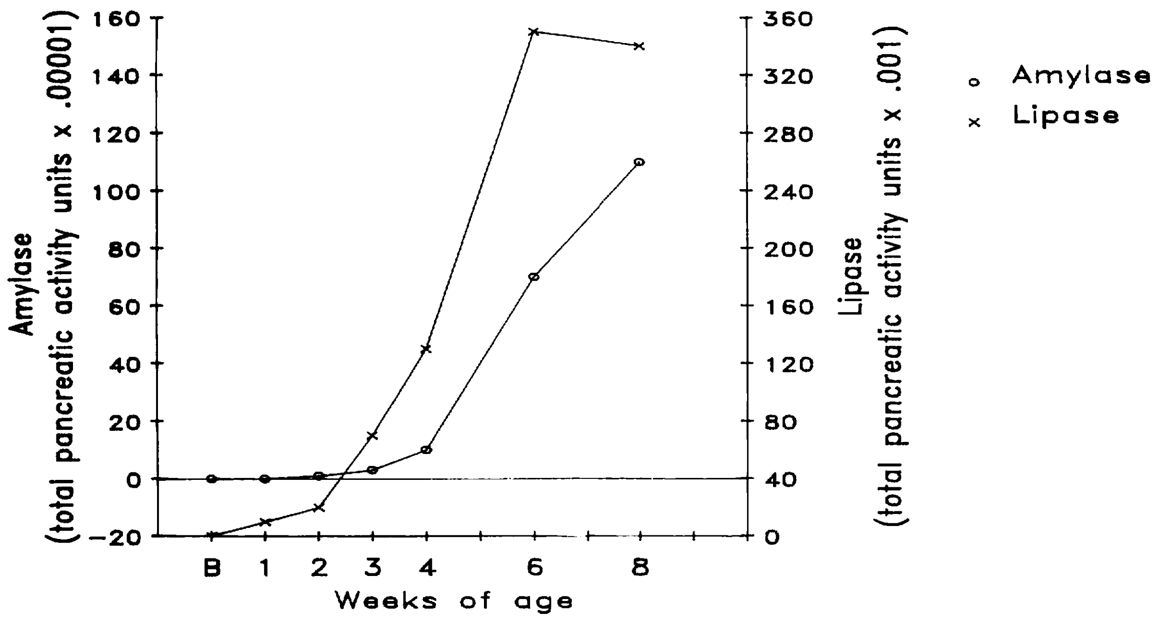


FIGURE 2
THE EFFECT OF AGE ON PANCREATIC AMYLASE AND LIPASE ACTIVITY



Data adapted from Corring et al., 1978 and Jones, 1986.

FIGURE 3
EFFECT OF HIGH NUTRIENT DENSITY DIET (HND) ON STARTER PIG PERFORMANCE (TRIAL 2)